ENGINEERING INFORMATION RECORD

Document Identifier - DRAFT - B

Title **REFINEMENTS TO THE AREVA/ALDEN/PCI STRAINER TEST PROTOCOL**

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N/A				

Note: P/R/A designates Preparer (P), Reviewer (R), or Approval (A).

Record of Revisions

Revision	Date	Pages/Sections Changed	Brief Description
Draft	January 2007	All	Draft Issue

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1.0 PURPOSE

The purpose of the revised test protocol is to identify modifications to the existing procedure for testing and measuring the performance of a Performance Contracting Inc. (PCI) Sure-Flow Suction Strainer module based on plant specific flow rate and debris mix conditions expected in a containment following a postulated design basis accident. The primary modifications to the previous test protocol include testing of a full scale strainer module to accurately represent near-strainer debris motion and incorporation of WCAP-16530-NP (Reference 4.3) generated chemical surrogates to simulate chemical effects.

The testing protocol proposed herein is only valid for the full scale suction screen arrangements that integrate flow control to all sections of the screens and/or modules, which is applicable to all PCI Sure-Flow® Strainer arrangements.

2.0 MODIFICATIONS TO EXISTING PROTOCOL

2.1 Near-Strainer Flow Fields

For typical containment PCI Sure-Flow strainer installations, it is expected that the opportunity exists in the regions surrounding the strainer installation for debris to settle to the floor prior to interacting with the strainer disks. Further, it is expected that approach velocities near the floor in the region of the modules and the vertical component of the velocity below the modules are not sufficient to move all of the material to the screen surfaces.

To correctly represent prototypical approach flow patterns (flow patterns approaching the screen array which can be influenced by equipment, structures, piping, etc.) and velocities in the test protocol, a module with full size disks will be tested in the flume, as is permitted by scaling limitations. Further, the geometry of the flume will be adjusted to reproduce the approach flow velocities and velocity gradients as they are predicted to exist in the actual containment during recirculation.

To reproduce the correct approach flow patterns and correctly represent prototypical debris transport, the following procedures are presented:

2.1.1 Prediction of Strainer Module Approach Flow Patterns

Prediction of prototypical strainer module approach flow velocities is necessary to define representative approach flow patterns and velocities in the test facility. This requires analysis of containment flow patterns to each module in each new strainer array installed in the containment. Several approaches may be considered to obtain the flow pattern and velocity information required including a nodal network flow model approach and Computational Fluid Dynamics (CFD). To obtain the required information using CFD, a model of the containment flow patterns and turbulence intensities with the PCI Sure FlowStrainer array installed must be prepare and simulations run for the break scenario to be tested in the flume.

Using the CFD predicted results, the flow stream to each module is identified by numerically seeding each module surface with massless tracer particles and back-calculating their trajectories through the computational domain. This analysis will identify the three dimensional volume within which all flow enters the module.

Within each of the volumes identified for each module in the installed array, vertical cross sectional average velocities parallel to the floor at up to 10 locations upstream (maximum interval between cross sections is limited to 1 ft) of each module (as measured along the centerline of the three dimensional volume) will be quantified.

The average velocities at each cross section identified will be averaged for each of the 10 upstream locations, across all modules. The resulting average velocities will then be used as the basis to configure the test flume geometry to reproduce a 'typical' approach velocity variation for the installed strainer array (see Figure 1). If multiple strainer arrays exist for a given installation, the array with the highest/bounding approach velocities will be selected.

Alternative methods for determining the approach flow patterns to the tested module may be selected by the utility. The direct input needed to conduct the flume testing is identification of prototypical flow velocities at up to 10 pre-determined cross sectional locations upstream of the test module.

2.1.2 Prediction of turbulent energy levels from CFD

The prediction of turbulent energy levels in the vicinity of the prototype strainer array is necessary to define prototypical mixing energy that exists in the transport zone. It is recognized that some installations will not require the addition of energy to the flume test protocol. As such, methodology for reproducing energy levels in the test flume is plant-specific and is based on CFD- predicted turbulence levels and associated turbulence characteristics. Plant specific containment geometries and strainer array locations must be reviewed to determine the effects of concentrated water falls and other inflows on approach flow to the strainer test module.

Note: The presence of isolated mixing energy sources that only affect minor portions of the screen arrangement may be ignored in the test configuration. The reason for ignoring isolated mixing energy near a single module or two is that it's not representative of the whole strainer arrangement and that the qualification test needs to represent the majority of the modules and arrangement.

2.1.3 Representation of Approach Velocities in Flume

The approach velocities and velocity gradients upstream of the flume test module can be adjusted to match prototypical values by modifying the flume side walls. Figures 2 and 3 show conceptual rendering of typical flume set-up. The shape of the converging side walls is dictated by the required average cross sectional velocities approaching a typical strainer module as defined by the CFD simulation (or equivalent). It is envisioned that the average approach velocities and velocity gradients predicted for the prototype be achieved in the flume using linear side walls adjusted to the correct angle to reproduce those velocities and velocity gradients. Surface mixing energy will be introduced, if required, using downcommers at or below the water surface.

2.2 Debris Preparation and Introduction into the Test Flume

Debris will be prepared in 5 or 10 gallon buckets and thoroughly mixed to achieve a homogeneous slurry. NUKON® fibrous insulation with binder will be heat-treated by baking to simulate in-service condition as directed by the client. Size classification of fibrous debris will be as defined in Appendix III and Appendix VI of the SER (Reference 4.1) or as used in the site specific analysis. This is critical since debris transport in the near-strainer region is to be reproduced in the test flume. The quantity, by each size classification, is to be provided by each plant. Further, the plant is to provide information concerning the type of each form of particulate (powder, pieces or chips).

Surrogates for certain particulate debris material will be discussed in subsequent sections. The quantity of particulate, by each size classification, is to be provided by the plant. For RMI debris, the size classification and distribution is as defined per Figure 3-7 of NRC NUREG/CR-6808 (Reference 4.2) or as used in the site specific analysis. The quantity of RMI, by each size classification, is to be provided by plant. RMI can be omitted from the debris mix at the plant's direction.

Miscellaneous debris such as Tags, labels, etc. is to be provided by the plant. Latent fiber and particulate quantities are also to be provided by the plant.

2.3 Selection of debris surrogates

Latent debris surrogate(s) shall be NUKON® fines for fibrous debris and PCI PWR dirt mix for particulates in accordance with Table V-2 of the SER (Reference 4.1), or as used in the site specific analysis, for size distribution. Zinc coatings surrogate shall be tin in powder form since zinc powder and tin powder have similar density, size, and shape. Epoxy and / or non-primer coating surrogates in powder form shall be walnut shells, stone flour or other surrogates having similar density, size, and shape as the debris. Paint chips (the transported paint chips) shall be formed from the dry film of the coating material or shall be formed from a surrogate material of similar density, size and shape. Miscellaneous debris (labels, etc) will be site specific materials and the quantity is to be provided by plant for one module.

WCAP (Reference 4.3) generated chemical precipitates will be used to simulate chemical effects. Specifically, chemical precipitates will be generated and verified at Alden per WCAP (Reference 4.3) methodology. Chemical material will be manufactured in mixing tanks and introduced into the flume within 30 days of its manufacture.

2.4 Methodology for Introduction of Debris into Test Flume

The following methodology is proposed for introduction of the debris material into the test flume:

- Produce batches of homogeneous debris (fibers, particulates, RMI, misc.) in buckets with water. Place contents of buckets in conical pre-load tank above test flume and / or in the debris drop zones of the flume.
- Fill the flume with water and / or debris to a predetermined level allowing for additional volume introduction with debris and manufactured chemical quantities.
- Start flume recirculation pump. Note: Some test conditions may require debris to be placed in the flume prior to start of recirculation.
- For debris introduced via the pre-load tank, open the pre-load tank valve and introduce debris-laden flow into the flume through the pre-load line distribution manifold at a pre-determined rate.

The following methodology is proposed for introduction of WCAP (Reference 4.3) generated chemical debris surrogate into the test flume.

A. Add chemical debris prior to start of recirculation. (Note: The volume of water/chemical surrogate to be included in a test may be so large as to require its introduction as part of the flume fill process)

B. Add chemical debris after start of recirculation. (Note: The increase in water volume needs to be accounted for prior to introduction; so as not to violate the test screen submergence criteria.)

- Premix master batch of chemical surrogates, generated per the WCAP methodology, and place in the pre-load tank located above the flume.

- Introduce chemical debris into the test flume using a similar manifold injection system as that used for the other debris as described above.

- The rate of introduction of WCAP generated material is to be determined from plant specific pool conditions/chemistry.

2.5 Test Termination Criteria

In this test protocol, the minimum test termination criteria shall be to terminate the flume testing once the rate of change in head loss is less than 1% in 30 minutes and until the pool volume has recirculated at least 5 times by calculation from the start of the test.

2.6 Bypass Sampling

Provisions will be made in the new flume test facility for taking bypass samples using the Alden-designed insitu isokinetic sampling ports. Bypass sampling will be performed on a timed integrated basis.

3.0 TEST FACILITY

The proposed test flume will be located adjacent to the existing scaled strainer test flume in Building 11 at Alden Research Laboratory, Inc. in Holden, Massachusetts. The new facility will be capable of accommodating a full size strainer module in either a floor-mounted or recessed pit-mounted configuration. Flow from the strainer will be re-circulated in a closed loop return line capable of discharging flow into either end of the flume with the option to divert a portion of the flow to a movable overhead discharge line to simulate turbulent energy, if required.

The facility is designed to accommodate changes to the internal surfaces of the flume so that plant-specific approach flow velocities and velocity gradients can be reproduced and near-strainer module transport of debris simulated. The vertical orientation of each module installation will be representative of the prototype installation and the correct water surface elevation will be maintained to represent the field submergence at the start of recirculation. The facility will also be capable of modeling rising water levels through introduction of additional water from a separate inflow line.

Provisions will be made in the design of the return piping to accommodate isokinetic sampling of debris material passing downstream of the strainer module during testing.

3.1 Flume Geometry

The main component of the new test facility is a steel flume measuring 10 ft wide by 34 feet long by 6 ft high. The flume is re-enforced with tubular box steel to minimize both wall and floor deflection at full capacity (2040 cu ft (15,260 gallons) of water). Currently located in Building 25, the large steel flume will be transported to Building 11 where ceiling heights are sufficient to accommodate the addition of a 6 ft deep pit to the tank. A three dimensional rendering of the tank geometry with the modification to include a pit at one end, is shown in Figure 4.

The steel flume will be used as a containment shell within which wood and Plexiglas walls will be constructed to reproduce the required approach flow velocities and velocity gradients approaching the test module. These internal walls will be removed and re-constructed for each individual plant test sequence since the configuration of these walls will depend in each individual plants approach flow velocity field. Since clearances between the steel flume walls and the internal walls may be small for some plant configurations, video cameras, connected to monitors, will be used to accommodate real-time observations through acrylic windows in the internal walls. For testing at room temperature, the top of the flume will be open for water surface observation.

The flume will be elevated approximately 4 ft above the main laboratory floor with the pit resting on the floor of the building sump whose elevation is 2 ft below the main floor level. A gantry hoist and rail system will be used to install the strainer modules in the tank and transport the large tanks of debris to the distribution manifolds located above the tank.

3.2 Full Size Strainer Module

A full size PCI Sure Flow strainer module with prototype disk size, disk spacing and core tube geometry will be used in the proposed testing program. The centerline of the prototype module will be located. The correct distance from the flume floor and all connecting flanges, floor plates, etc will be represented in full scale. This is necessary to reproduce the influence of these components on water velocities and debris motion in the near-strainer regions.

Testing at two different pump flows; one to represent the screen's surface area approach velocity and one to representing the approach velocity to the circumscribed area would not be required with full scale module testing. This is required when less than full size modules are used as test modules. A single pump flow through the full size module will achieve both screen approach velocities.

3.3 Flow Loop

The basic flow loop is shown schematically in Figure 5. Water will be circulated through the test loop using two Aurora-class series 330 Centrifugal Pumps with flow capacities of up to 700 gpm and head ratings of 140 ft of water each. These pumps are also rated for water temperatures of up to 200 ^{o}F if running at elevated water temperatures is required. The pump speed will be computer controllable using Variable Frequency Motor Controllers to maintain steady flow through the strainer and debris bed. Automated valve control may also be utilized to control flow rate. Flow through the return lines will be measured using standard ASME Orifice plate flow meters with pressure tap output fed through Rosemont DP cells/transmitters to data acquisition computers. Two data acquisition computers will be used to read the DP cell output simultaneously to provide a single-failure redundancy to the data logging system. The output from two digital temperature probes will also be monitored through the data acquisition system. Strainer head loss will be measured using a pressure tap array located just downstream of the strainer module discharge pipe with the output fed through a Rosemont DP cell to the data acquisition computer. The data acquisition computers will be Dell Laptops configured for data acquisition (laptop data acquisition computers are used to take advantage of their uninterrupted power feed features). External USB data acquisition cards by Data Translation or National Instruments will be used to process data signals and LabView data acquisition software will be used to collect data and control instrumentation.

The main loop piping will be 6 inch PVC with a maximum temperature rating of 140 ^{o}F. Transition pieces from plant-specific strainer core tube flanges will be custom fabricated to join with the 6 inch PVC. Manual valves will be used to isolate pipe runs depending on the configuration of the flume and the return pipe segments utilized.

3.4 Debris Injection System during Recirculation

The test debris (fibrous, particulate, etc.) will be held in a 50 gallon pre-load tank above the new flume (see Figure 3), supported and managed by a gantry crane. The pre-load tank will include a conical bottom and be positioned approximately 2 feet above the test flume. A vertical manifold pipe array (up to 4 discharge orifices) from the bottom of tank to test flume, penetrating just below the water surface, will be used to introduce the debris into the flume just below the water surface. A ball valve or similar device will be used to control the discharge of material from the head tank. A series of staggered angled perforated baffle plates, installed over the cross section of the flume, will be used to distribute the debris across water column and help straighten the inflow. The baffle system will be designed using CFD to provide optimum distribution of the debris into the flume and minimize density current resulting from the introduction process (Figures 2 and 3).

The WCAP (Reference 4.3) chemical debris will be held above the flume in a similar manner using a separate mixing tank with a conical bottom. A second vertical manifold pipe array of smaller diameter than that used for the main debris (up to 8 discharge orifices) will transfer material from the mixing tank to the test flume. A ball valve or similar device will be used to control the discharge of material from the head tank. The chemical effluent will discharge onto the same series of staggered angled perforated baffle plates as discussed previously to spatially distribute the chemical debris and minimize density currents in the flume.

4.0 REFERENCES

4.1 NEI 04-07, “Pressurized Water Reactor Sump Performance Evaluation Methodology”, Volume 2, “Safety Evaluation by the Office of Nuclear Reacotr Regulation Related to NRC Generic Letter 2004-02, Revision 0”, December 2004

4.2 NUREG/CR-6808, “Knowledge Based for the Effect of Debris on Pressurized Water Reactor Emergency Core Cooling Sump Performance”, February 2003

4.3 WCAP-16530-NP & Spreadsheet, “Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191”, February 2006 (or subsequent revisions)

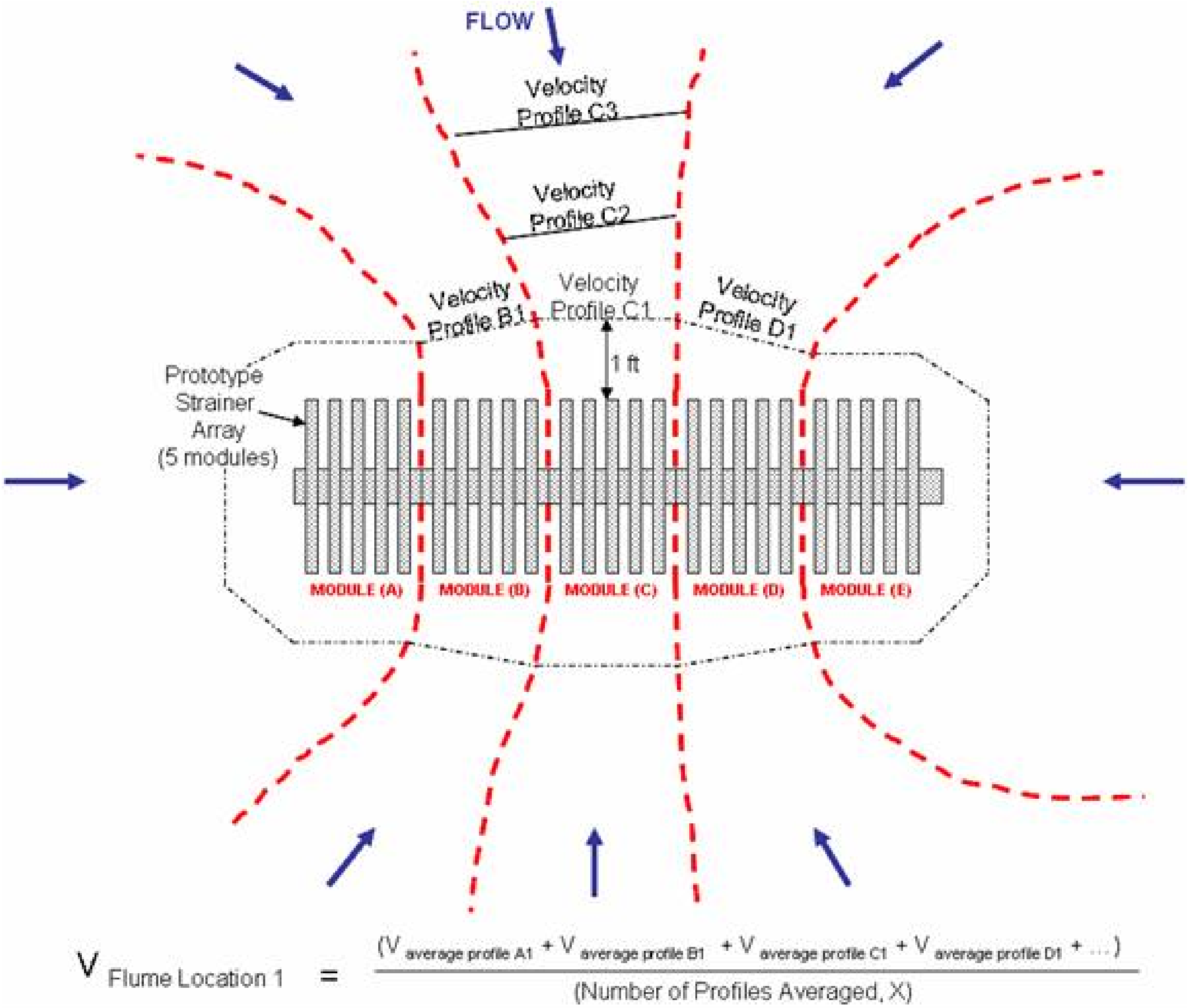

Figure 1 Graphical Representation of Average Approach Flow Calculation

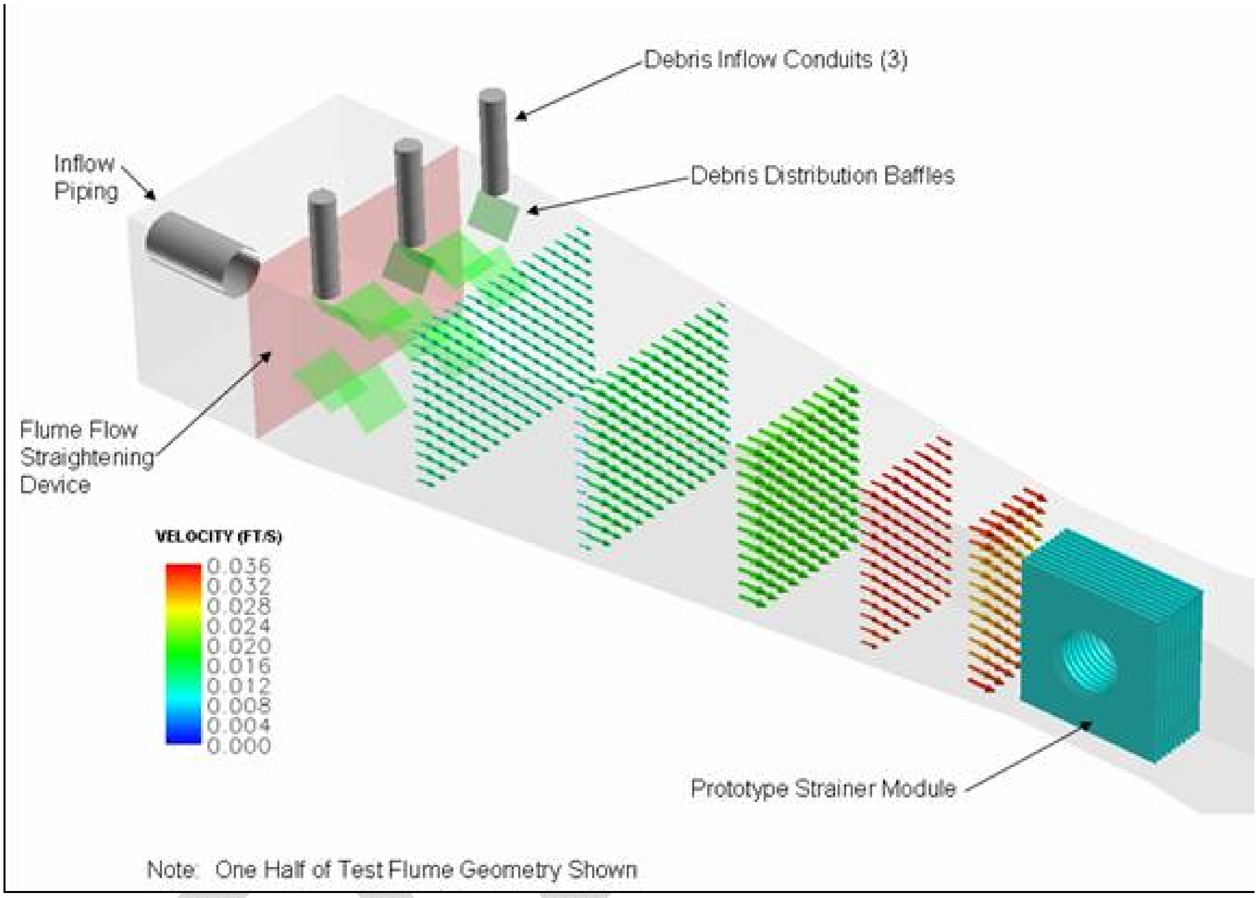

Figure 2 CFD Predicted Average Approach Flow Velocity Profiles Upstream of Test Strainer Module

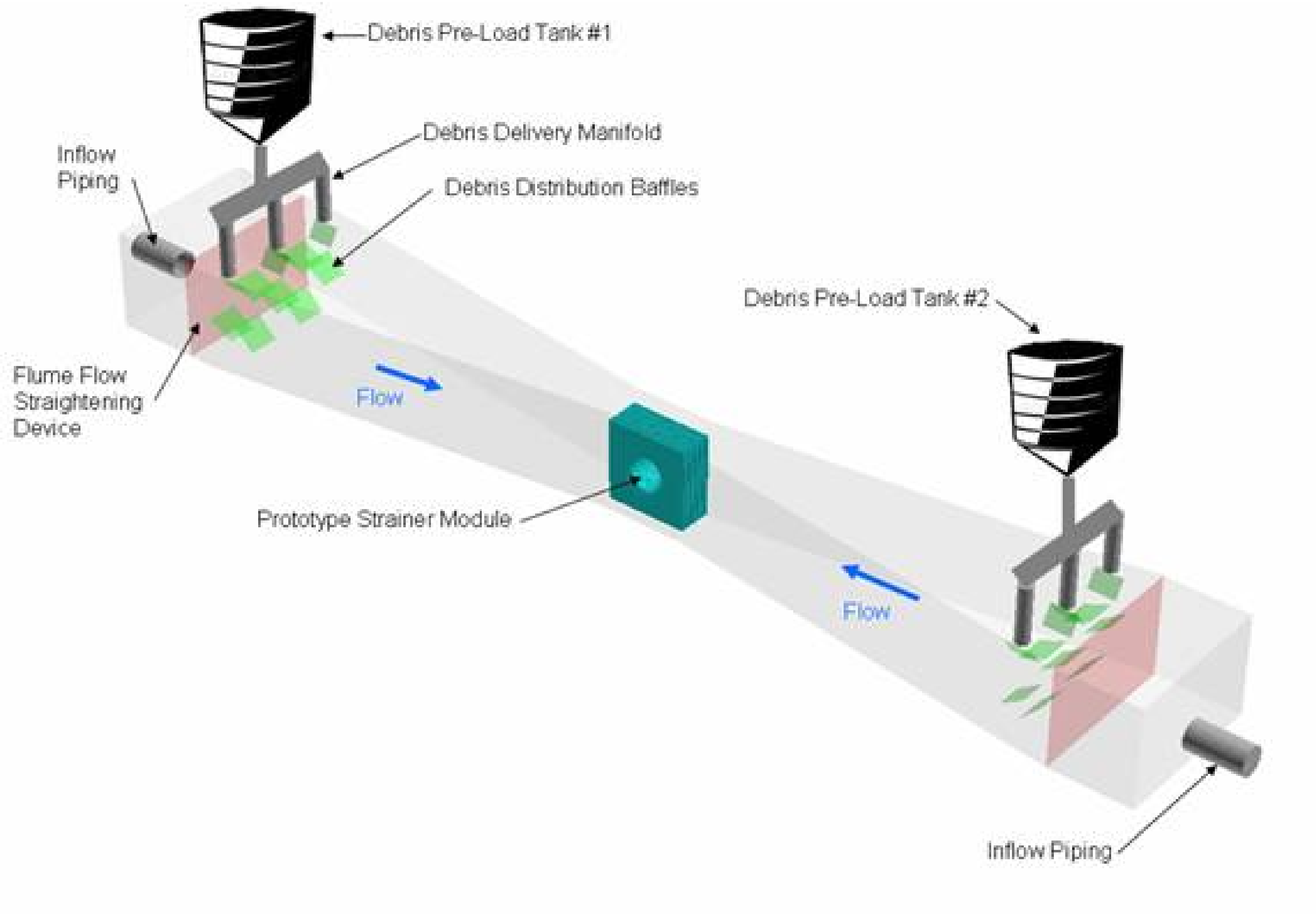

Figure 3 Conceptual Flume Setup

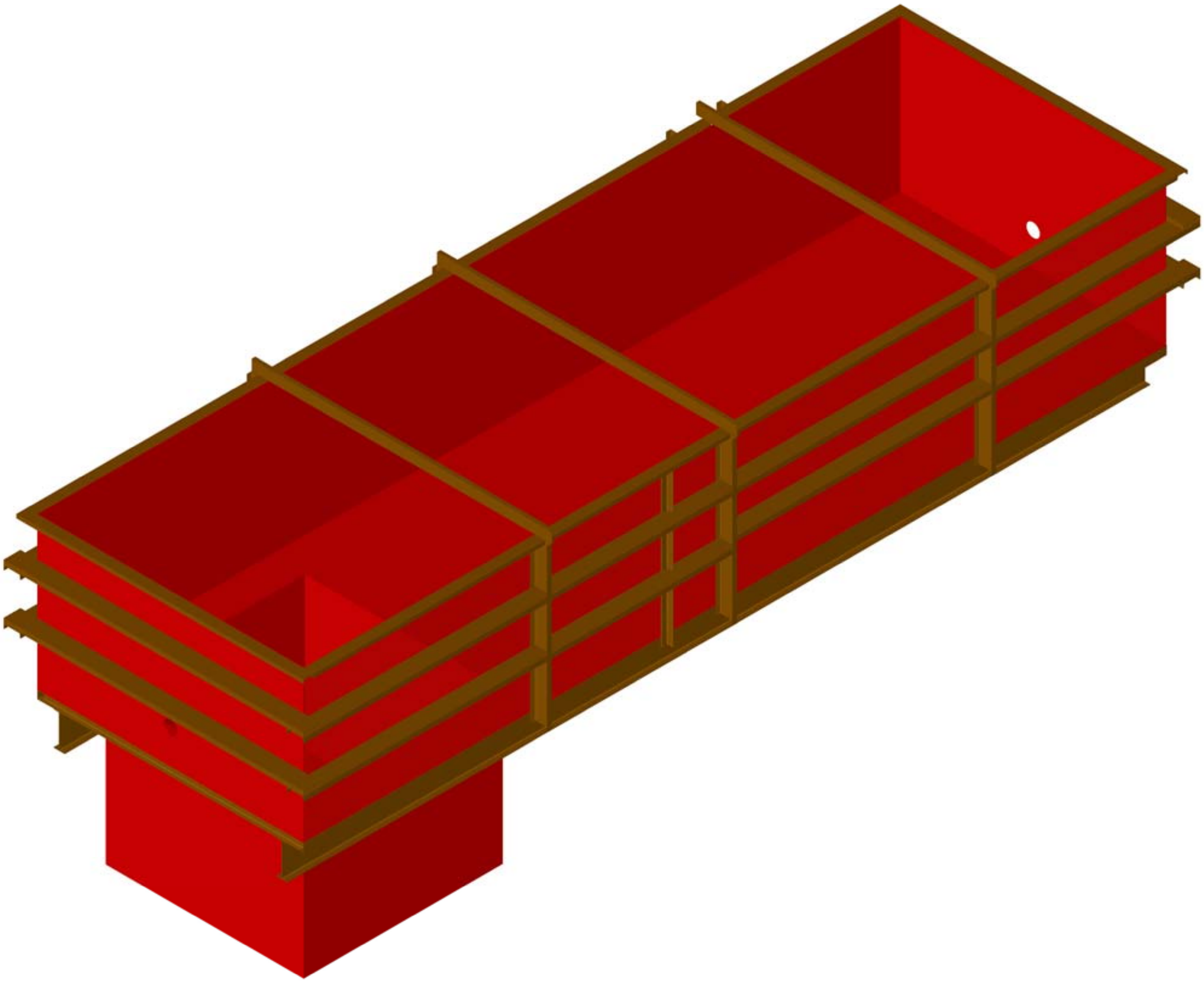

Figure 4 10 ft Wide X 34 ft Long X 6 ft High Steel Reinforced Test Flume

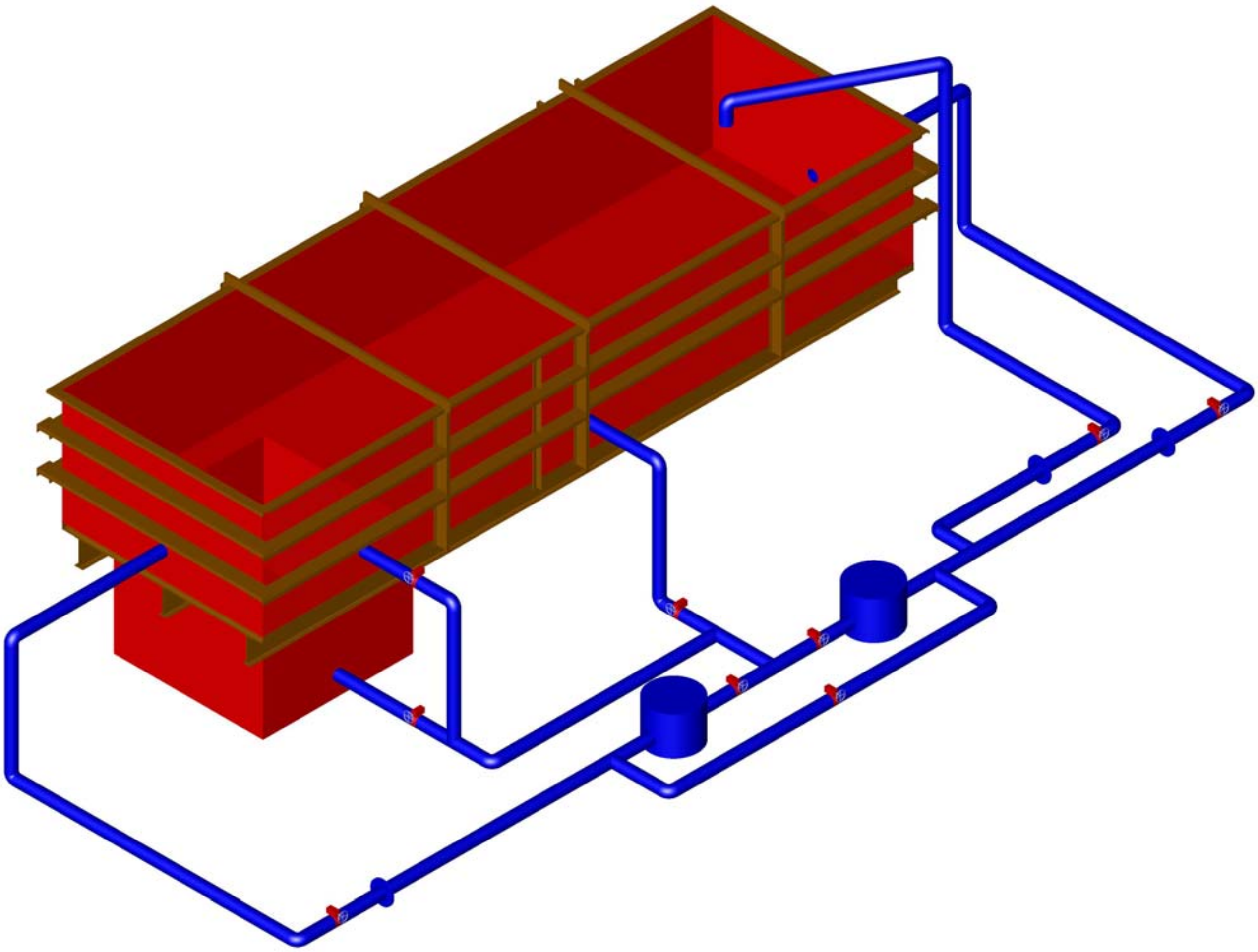

Figure 5 Flume With Basic Flow Loop